DEVELOPMENT AND DETERMINATION OF VOLTAGE-FAULT-LOCATION AND LINE-FAULT-LOCATION (LENGTH OF LINE) ON LONG TRANSMISSION-LINE (200 MILE = 320 KM) (IFLM)

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Abstract

Fault location and fault-voltage problems have been presented as a major challenge in electrical power system analysis, most of these methods uses voltage and currents measurements at either one ends or both ends of a transmission line. This work presents a fault-location/fault-voltage problems. An improved fault location model (IFLM) are developed to search for fault location in a long transformation line say (200 mile), thereby determining a set of values for a set of unknown system state variables, based on certain criterion making use of the measurements mode from the system under consideration.

Keywords: *Fault Location, fault-voltage-location-long transmission line, impedance matrix, Admittance line-fault-location and voltage buses.*

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1. INTRODUCTION

Fault location in a long transmission line (200 mile = 320km) using an improved fault-location model (IFLM) are described and presented. Many contributions have been made by different references based on: the use of voltage and currents phasor one terminal which is based on reactive power, use of voltage and currents phasor at both ends, use of three-phase analysis and which uses a least – square – estimate to obtain fault point distance, the method is to convert time domain and then use critical neutral network to estimate fault location. This work formulate and presents a model based on impedance matrix and estimation, based on impedance equation, that are applied on a transmission line to determine fault voltage/fault location. [1]

2. ANALYSIS AND MODEL: THE PROPOSED MODEL (IFLM)

Consider a transmission line as shown in fig. 1.0 for analysis. The three phase – source impedance matrices are Z_{s1abc} (Ω) and Z_{S2abc}(Ω). These are assumed to be known and equal the Thevenin equivalent system models of bus 1 and 2 respectively. "L" is the length of the long-transmission line (200 mile = 320km). The transmission line has three-phase impedance Z_{abc}Ω/mile (formed by self and mutual impedance among phases). [2,3]

That can be presented in the form: 3-phase [a b c]

$$\left.\begin{array}{l} Zabc = \begin{bmatrix} Zaa & Zab & Zac \\ Zba & Zbb & Zbc \\ Zca & Zcb & Zcc \end{bmatrix} \\ \text{Or} \\ Z_{123} = \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} \\ Z_{21} & Z_{22} & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix} \end{array}\right\} \quad (1)$$

- For a three – phase analysis this line would yield a bus impedance/admittance. The bus admittance matrix will take the form:

$$Z_{Bus} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \quad (2)$$

Or

$$Y_{Bus} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \quad (3)$$

- From equ. (2) the element is a matrix of Dimension 3 x 3; as shown in fig. 2, the fault point considered as the third bus. The third bus is consider to be the faulted bus. Then the change in the bus voltages on all the three buses due to the fault can be obtained by the following equation: [4]

$$\begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \Delta V_3 \end{bmatrix} = Z_{bus}\, fault \begin{bmatrix} [0] \\ [0] \\ I_{Fabc} \end{bmatrix} \quad - \quad - \qquad (4)$$

- Similarly, a case when the reactance are not given, therefore it is convenience to obtain Z_{1Bus} directly rather than inventing Y_{1Bus}.
- Also if $Y_{0,Bus}$ is singular and then $Z_{o,Bus}$ cannot be obtained from it.
- Hence, in such conditions above, we can apply a simple technique of unit current – injections approach. [5,6]
- That is for the 2-Bus in fig. 1.0 above, we can write the matrix equation relating voltage and currents, as:

$$\begin{bmatrix} V_1 \\ V_2 \\ \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} \quad - \qquad (5)$$

- Now injecting unit currents at bus 1 (that is I_1, = 1, and $I_2 = 0$)

Then we have:

$$Z_{II} = V_1$$

$$Z_{21} = V_2 \quad - \qquad (6)$$

- Similarly, by injecting a units currents at bus 2 (that is $I_2 = 1$, $I_1 = 0$), then we have:

$$Z_{12} = V_1$$

$$Z_{22} = V_2 \quad - \qquad (7)$$

This, Z_{bus} could be obtained directly by this idea:

$$Z_{Bus} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} = \begin{bmatrix} V_1 & V_1 \\ V_2 & V_2 \end{bmatrix} \quad - \qquad (8)$$

Now, interpreting the parameters of equation (4) we have:
[O]: null matrix of dimension is (3 x 1)

I_{Fabc}: Three phase fault current at the faulted bus 3; dimension of I_{Fabc} is (3 x 1).

ΔVi: Change in the three phase voltages of bus 1 due to the fault at bus three.

ΔVi, dimensions (3 x 1).
$Z_{Busfault}$: Three phase bus-impedance matrix with the fault considered at bus three dimensions is (9 x 9) rewriting equation (4) we have:

$$= Z_{bus}\, fault \begin{bmatrix} [0] \\ [0] \\ I_{Fabc} \end{bmatrix} = \begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \Delta V_3 \end{bmatrix}$$

Or

$$\begin{bmatrix} [0] \\ [0] \\ I_{Fabc} \end{bmatrix} = Z_{bus}\, fault^{-1} \begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \Delta V_3 \end{bmatrix}$$

Similarly we have:

$$\begin{bmatrix} [0] \\ [0] \\ I_{Fabc} \end{bmatrix} = Y_{bus}\, fault \begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \Delta V_3 \end{bmatrix} \quad - \qquad 9$$

- In equation (4) $Y_{Busfault}$ is the three-phase bus admittance matrix of dimension (9 x 9) which is equal to the inverse of $Z_{Busfault}$
- Each elements of $Y_{Bus\ fault}$ is a matrix of dimension (3 x 3).
- Bus admittance matrices are related to the physical configuration of the corresponding power system.
- Elements of the Bus admittance matrix Y_{Bus} (before fault) are known to us.
- Now using the correction of the system in fig.2 due to fault condition; the elements of $Y_{Bus\ fault}$ can be related to the elements of Y_{Bus} as given as:

$$Y_{Busfault} = \begin{bmatrix} Y_{11}' & Y_{12}' & Y_{13}' \\ Y_{21}' & Y_{22}' & Y_{23}' \\ Y_{31}' & Y_{32}' & Y_{33}' \end{bmatrix} \quad - \qquad (10)$$

Where:

$$Y_{11}' = Y_{11} - \frac{Y_{abc}}{L} + \frac{Y_{abc}}{L_1} \quad - \qquad (11)$$

Y'_{12} = Y_{21} = $[0]_{3 \times 3}$ -- (12)

$$Y'_{13} = Y_{31} = \frac{Y_{abc}}{L_1} \quad - \quad (13)$$

$$Y'_{22} = Y_{22} - \frac{Y_{abc}}{L} + \frac{Y_{abc}}{L_2} \quad -(14)$$

$$Y'_{23} = Y_{32} = -\frac{Y_{abc}}{L_2} \quad -(15)$$

$$Y'_{33} = \frac{Y_{abc}}{L_1} + \frac{Y_{abc}}{L_2} + (Zabc)^{-1} \quad --(16)$$

Where:
L_1 and L_2: Are the distances of the fault point from bus 1 and 2 respectively, is shown in fig 2.
L: is the total length of the transmission line (200mile = 320 km)
Zf_{abc} is the three – phase fault impedance matrix.
Y_{abc}: is the inverse of the three phase line impedance matrix per unit length gives as:

$$Y_{abc} = \frac{1}{(Z_{abc})} = (Zabc)^{-1} \quad (17)$$

From equations (9, 10, 11, 12, ...16) the following equation can be formulated, but we can recalled that;

$$\begin{bmatrix} [0] \\ [0] \\ I_{Fabc} \end{bmatrix}_{3\times3} = Y_{bus}\, fault \begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \Delta V_3 \end{bmatrix}$$

Then,

$$[O]_{3\times3} = Y_{Bus} \begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \Delta V_3 \end{bmatrix}$$

Or

$$[O]_{3\times3} = \begin{bmatrix} O & O & O \\ O & O & O \\ O & O & O \end{bmatrix} \quad -- \quad (18)$$

$$[Y_{Bus\ fault}] = \begin{bmatrix} Y'_{11} & Y'_{12} & Y'_{13} \\ Y'_{21} & Y'_{22} & Y'_{23} \\ Y'_{31} & Y'_{32} & Y'_{33} \end{bmatrix} \quad (19)$$

$$\begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \Delta V_3 \end{bmatrix} = change\ at\ Bus\ 1, 2, 3 \quad (20)$$

Where: $Y'_{11} = Y_{11} - \frac{Y_{abc}}{L} + \frac{Y_{abc}}{L_1}$

$Y'_{12} =$ - - - - -
$Y'_{13} =$ - - - - -
$Y'_{22} =$ - - - - -
$Y'_{23} =$ - - - - -
$Y'_{33} =$ - - - - -

This implies that:

$$[O]_{3\times3} = \left(Y_{11} - \frac{Y_{abc}}{L}\right)\Delta V_1 + \frac{Y_{abc}}{L_1}\Delta V_1 - \frac{Y_{abc}}{L_1}\Delta V_3 \quad - - - \quad (21)$$

$$[O]_{3\times3} = \left(Y_{22} - \frac{Y_{abc}}{L}\right)\Delta V_2 + \frac{Y_{abc}}{L_2}\Delta V_2 - \frac{Y_{abc}}{L_2}\Delta V_3 \quad - - - \quad (22)$$

Variable L_1 and L_2 = L - (23)

- Since voltages at bus 1 and 2 are continuously measured, therefore ΔV_1 *and* ΔV_2 are known equation.
- The unknown equation (21, 22, and 23) are the fault voltage (ΔV_3) and fault location are: (L_1 and L_2) respectively.
- However, we can determined and obtained the formulation of fault location (L_1) as follows:
- Invoking and rewriting equation (21) and (22) into another form we have:

$$-\left(Y_{11}-\frac{Y_{abc}}{L}\right)\Delta V_1 =$$

$$\frac{\Delta V_1}{L_1}Y_{abc}-\frac{\Delta V_3}{L_1}Y_{abc} = \left(\frac{1}{L_1}\Delta V_1-\frac{1}{L_1}\Delta V_3\right)Y_{abc} \quad - - - - \quad (24)$$

or

$$\left(\frac{1}{L_1}\Delta V_1 -\frac{1}{L_1}\Delta V_3\right)Y_{abc} = -\left(Y_{11}-\frac{Y_{abc}}{L}\right)\Delta V_1$$

- Then divide through by Y_{abc}:

$$= \left(\frac{1}{L_1}\Delta V_1-\frac{1}{L_1}\Delta V_3\right)\frac{Y_{abc}}{Y_{abc}} = -\left(Y_{11}-\frac{Y_{abc}}{L}\right)\frac{\Delta V_1}{Y_{abc}} \quad - - - - \quad (25)$$

This implies:

$$= \left(\frac{1}{L_1}\Delta V_1-\frac{1}{L_1}\Delta V_3\right) = -Y_{abc}^{-1}\left(Y_{11}-\frac{Y_{abc}}{L}\right)\Delta V_1$$

That is;

$$\frac{1}{L_1}\Delta V_1-\frac{1}{L_1}\Delta V_3 = -Y_{abc}^{-1}\left(Y_{11}-\frac{Y_{abc}}{L}\right)\Delta V_1$$

$$= -Z_{abc}\left(Y_{11}-\frac{Y_{abc}}{L}\right)\Delta V_1$$

$$\frac{1}{L_1}\Delta V_1-\frac{1}{L_1}\Delta V_3 = Z_{abc}\left(\frac{Y_{abc}}{L}-Y_{11}\right)\Delta V_1 \quad - - - \quad (26)$$

- Similarly, we can also write as:

$$\frac{1}{L_2}\Delta V_2-\frac{1}{L_2}\Delta V_3 = -Y_{abc}^{-1}\left(Y_{22}-\frac{Y_{abc}}{L}\right)\Delta V_2$$

Also,

$$\frac{1}{L_2}\Delta V_2-\frac{1}{L_2}\Delta V_3 = Z_{abc}\left(\frac{Y_{abc}}{L}-Y_{22}\right)\Delta V_2 \quad - - - - \quad (27)$$

- Further rewriting equation (26) and (27) we have:

$$\left(\frac{1}{L_1}\right)\Delta V_1-\left(\frac{1}{L_1}\right)\Delta V_3 = Z_{abc}\left(\frac{Y_{abc}}{L}-Y_{11}\right)\Delta V_1 \quad - - - - \quad (28)$$

- Similarly

$$\left(\frac{1}{L_2}\right)\Delta V_2-\left(\frac{1}{L_2}\right)\Delta V_3 = Z_{abc}\left(\frac{Y_{abc}}{L}-Y_{22}\right)\Delta V_2 \quad - - - - \quad (29)$$

This implies that:

$$X\Delta V_1(1)-X\Delta V_3(1) = S = Z_{abc}\left(\frac{Y_{abc}}{L}-Y_{11}\right)\Delta V_1 \quad - - - - \quad (30)$$

That is;

$$= Z_{abc}\left(\frac{Y_{abc}}{L}-Y_{11}\right)\Delta V_1 = S \quad - - - - - - - \quad (31)$$

Similarly;

$$Y\Delta V_2(1) - Y\Delta V_3(1) = K = Z_{abc}\left(\frac{Y_{abc}}{L}-Y_{22}\right)\Delta V_2 \quad - - - - \quad (32)$$

That is:

$$K = Z_{abc}\left(\frac{Y_{abc}}{L}-Y_{22}\right)\Delta V_2 \quad (33)$$

To solve for L_1, then go back grouping equation (30) and (32) we have

$$X\Delta V_1(1)-X\Delta V_3(1) = S(1) \quad - - \quad (34)$$

$$Y\Delta V_2(1) - Y\Delta V_3(1) = K(1) \quad -- \quad (35)$$

This implies:

- That is, the total length of the transmission line L is given as:

$$L = L_1 + L_2 \quad - \quad (35)$$

But, $X = \frac{1}{L_1}, \quad Y = \frac{1}{L_2}$

=> $L_1 = \frac{1}{X}, \quad L_2 = \frac{1}{Y}$ -- (36)

=> $L = \frac{1}{X} + \frac{1}{Y}$

$$L = \frac{Y+X}{Xy}$$

=> L XY = Y + X

LXY - Y = X

$$Y = X \big/ LX - 1 \quad - \quad (37)$$

- Further expressing equation (34) and (35), we can write;

$$X\Delta V_1(1) - X\Delta V_3(1) = S(1) \quad - \quad (34)$$

$$Y\Delta_2(1) - Y\Delta_3(1) = K(1) \quad - \quad (35)$$

- By mathematical manipulation principle their operation;

$$\times \Delta V_1(1) - S(1) = \times \Delta V_3(1) \quad - \quad (36)$$

$$Y\Delta V_2(1) - K(1) = Y\Delta V_3(1) \quad - \quad (37)$$

From 36: $$\frac{X\Delta V_1(1) - S(1)}{X} = \Delta V_3(1) \quad (38)$$

From 37: $$\frac{Y\Delta V_2(1) - K(1)}{Y} = \Delta V_3(1) \quad (39)$$

- Since, X and Y can be expressed in term of ΔV_3 then, we can equate them to be equal:

$$\frac{X\Delta V_1(1) - S(1)}{X} = \frac{Y\Delta V_2(1) - K(1)}{Y} \quad (40)$$

- **Case 1:** for $\frac{1}{X} + \frac{1}{Y} = L$

$$\frac{Y+X}{Xy} = L$$

$$X + Y = LXY$$

X = Lxy – y

X = Y (LX -1)

$$Y = X \big/ LX_{-1} \quad - \quad (41)$$

- **Cases 2:** For: $\frac{1}{X} + \frac{1}{Y} = \text{L}$

$$\frac{Y+X}{Xy} = L$$

X + Y = Lxy

Y = Lxy – X

Y = X(Ly – 1)

$$X = y \big/ Ly - 1 \quad - \quad (42)$$

- **Case 3:**

For L = $L_1 + L_2$ = Length of transmission line

- **Case 4:** Now recalling our previous equation (40):

$$\frac{X\Delta V_1 - S(1)}{X} = \frac{Y\Delta V_2(1) - K(1)}{Y} \quad -- \quad (40)$$

- Substituting values from case 2:

$Y = \frac{X}{XL - 1}$ into equation 40

We have:
That is keeping (LHS) and substituting

$Y = \frac{X}{XL - 1}$ in the (RHS), we have:

$$\frac{X\Delta V_1(1)-S(1)}{X}=\frac{\frac{X}{XL-1}\Delta V_2-K(1)}{\frac{X}{XL-1}} \quad - \qquad (43)$$

- Now cross – multiplying to the (LHS) and (RHS):

$$X\left(\frac{X}{XL-1}\right)\Delta V_1(1)-S(1)\left(\frac{X}{XL-1}\right)$$
$$= X\left(\frac{X}{XL-1}\right)\Delta V_2(1)-K(1).X \quad -- \qquad (44)$$

- Bringing the term of voltage for (ΔV_1 and ΔV_2):

$$\frac{X}{XL-1}.X\,.\,\Delta V_1(1)-X\,.\frac{X}{XL-1}\Delta V_2(1)$$
$$= \qquad \frac{X}{XL-1}.S\ (1)-X\,.\,K(1) \qquad - \qquad (45)$$

- Grouping them together:

$$\frac{X}{XL-1}.X\ \left(\Delta V_1(1)-\Delta V_2(1)\right)=\frac{X}{XL-1}.S(1)-X.K(1)$$
$$- \quad - \quad - \qquad (46)$$

- Dividing through by $\frac{X}{XL-1}$ to both side of the equation:

$$\frac{\frac{X}{XL-1}}{\frac{X}{XL-1}}.X\ \left(\Delta V_1(1)-\Delta V_2(1)\right)=\frac{\frac{X}{XL-1}}{\frac{X}{XL-1}}.S(1)$$
$$-\frac{K.X}{\frac{X}{XL-1}} \quad - \quad - \qquad (47)$$

Then we can continue as follows:

$$\frac{\frac{X}{XL-1}}{}\ \frac{\frac{X^2L-1}{X}}{}\left(\Delta V_1(1)-\Delta V_2(1)\right)=$$
$$\frac{X}{XL-1}\ .S(1)-\frac{XL-1}{X}\quad -.K.X.\frac{XL-1}{X} \qquad (48)$$

=> $X(\Delta V_1(1) - \Delta V_2(1)) = S(1) – K(XL-1)$

=> $X(\Delta V_1(1) - \Delta V_2(1)) = S(1) – KXL + K(1)$ -(49)

- Expanding the RHS:

$X(\Delta V_1(1) - \Delta V_2(1)) = S(1) – X\,LK(1) + K(1)$ - (50)

- Collecting like terms of X and grouping them, we have:

$$X(\Delta V_1(1) - \Delta V_2(1)) + XLK(1) = S(1) + K(1)$$

This implies that:

$$X[\Delta V_1(1) - \Delta V_2(1) + LK(1)] = S(1) + K(1) \qquad (51)$$

$$X=\frac{S(1)+K(1)}{\Delta V_1(1)-\Delta V_2(1)\times LK(1)}$$

But $X=\frac{1}{L_1}$, $Y=\frac{1}{L_2}$ from our relationship, in case, 1, 2, 3, respectively.

Then; $L_1 = {}^{1}\!/_{X}$

$$\frac{1}{L_1}=\frac{S(1)+K(1)}{\Delta V_1(1)-\Delta V_2(1)+LK(1)}$$

$$L_1=\frac{\Delta V_1(1)-\Delta V_2(1)+LK(1)}{S(1)+K(1)} \qquad - \qquad (52)$$

- Similarly, repeating the same technique for the fault location (L_2). Since equation (10 – 16), L_1 and L_2 are the distances of the fault point – location from Bus 1 and 2 respectively as shown in fig. 2, above, where L is the total distance of the long-transmission line.
- Recalling, the equating on case 1, case 2, case 3 and case 4 respectively for this considerations.

That is:

Case 1 - $Y = {}^{X}\!/_{LX-1}$

Case 2 -

$$ {}^{1}\!/_{X} + {}^{1}\!/_{Y} = L \quad or \quad X = {}^{Y}\!/_{LY-1}$$

Case 3 - $L = L_1 + L_2$

Case 4 - $$\frac{X\Delta V_1(1)-S(1)}{X}=\frac{Y\Delta V_2(1)-K(1)}{Y}$$

- Similarity, in this case substituting, X = $\frac{Y}{LY-1}$

into equation 40:

Now keeping (RHS) and substituting into the (LHS): X = $\frac{Y}{LY-1}$

$\frac{X\Delta V_1(1)-S(1)}{X}=\frac{Y\Delta V_2(1)-K(1)}{Y}$ from equation (40)

$$\frac{\left(\frac{Y}{LY-1}\right)\Delta V_1(1)-S(1)}{\frac{Y}{Ly-1}}=\frac{Y\Delta V_2(1)-K(1)}{Y} \qquad (53)$$

- Now cross – multiplying we have;

$$Y.\left(\frac{Y}{LY-1}\right).\Delta V_1(1)-S(1)Y$$

$$= \quad Y.\left(\frac{Y}{LY-1}\right).\Delta V_2(1)-K(1).\left(\frac{Y}{LY-1}\right) \quad -(54)$$

- Then grouping terms that change in V that is (ΔV) together:

$$Y\left(\frac{Y}{LY-1}\right).\Delta V_1(1)-Y\left(\frac{Y}{LY-1}\right)\Delta V_2$$

$$S.(1)Y-K(1)\left(\frac{Y}{LY-1}\right) \quad - \quad - \quad (55)$$

- Grouping them and factoring it out:

$$Y\left(\frac{Y}{LY-1}\right).(\Delta V_1(1)-\Delta V_2(1))=S(1)Y-K(1).\frac{Y}{LY-1} \quad - \quad - \quad (56)$$

- Divide through by $\frac{Y}{LY-1}$ to both side, we have:

$$\frac{.Y.\left(\frac{Y}{LY-1}\right)}{\left(\frac{Y}{LY-1}\right)}\left(\Delta V_1(1)-\Delta V_2(1)\right)=\frac{S(1)Y.}{\left(\frac{Y}{LY-1}\right)}-K(1)-\frac{.\left(\frac{Y}{LY-1}\right)}{\left(\frac{Y}{LY-1}\right)} \quad - \quad (57)$$

This means that:

$$Y.\left(\frac{Y}{LY-1}\right)\times\left(\frac{Ly-1}{Y}\right)\left(\Delta V_1(1)-\Delta V_2(1)\right)=S(1)Y.\times\left(\frac{Ly-1}{Y}\right)-K(1)\left(\frac{Y}{Ly-1}\right)\times\left(\frac{Ly-1}{Y}\right)$$

\- - - - - (58)

This give us as:

Y(ΔV$_1$(1) - ΔV$_2$(1)) = S(1) (Ly-1) – K(1) - (59)

- Expanding the term and collecting terms of Y – together.

Y(ΔV$_1$(1) - ΔV$_2$(1)) = LS(1) Y – S(1) – K(1) - (60)

Then we continue as:

Y(ΔV$_1$(1) - ΔV$_2$(1)) – LS(1)Y = - S(1) – K(1)- (61)

Simplifying further:

Y[(ΔV$_1$(1) - ΔV$_2$(1)) – LS(1)] = - S(1) – K(1)- (62)

Simplifying further again:

Y[(ΔV$_1$(1) - ΔV$_2$(1) – LS (1))] = - S(1) – K(1)- (63)

Making Y the subject of the expression we have:

$$Y=\frac{-S(1)-K(1)}{\Delta V_1(1)-\Delta V_2(1)-LS(1)} \quad - \qquad (64)$$

- But from our relationship X = $\frac{1}{L_1}$ and Y = $\frac{1}{L_2}$ - - (65)
- $$\frac{1}{L_2}=\frac{-S(1)-K(1)}{\Delta V_1(1)-\Delta V_2(1)-LS(1)} \qquad (66)$$

$$L_2=\frac{\Delta V_1(1)-\Delta V_2(1)-LS(1)}{-S(1)-K(1)} \qquad (67)$$

- From our mathematical relationship, the parameters in the equation which defined S and K are given as: recalling from previous equation 30 and 33.

$S = X\Delta V_1(1) - X\Delta V_3(1)$ - (30)

$$= Zabc\left(\frac{Yabc}{L} - Y_{11}\right)\Delta V_1$$

And

$K = Y\Delta V_2(1) - Y\Delta V_3(1)$

$$= Zabc\left(\frac{Yabc}{L} - Y_{22}\right)\Delta V_2 \quad (33)$$

- Thus, the fault – location L_1 and L_2 are developed and modeled as:

$$L_1 = \frac{\Delta V_1(1) - \Delta V_2(1) + LK(1)}{S(1) + K(1)} \quad (68)$$

and

$$L_2 = \frac{\Delta V_1(1) - \Delta V_2(1) - LS(1)}{-S(1) - K(1)} \quad - \quad (69)$$

Fig 1:

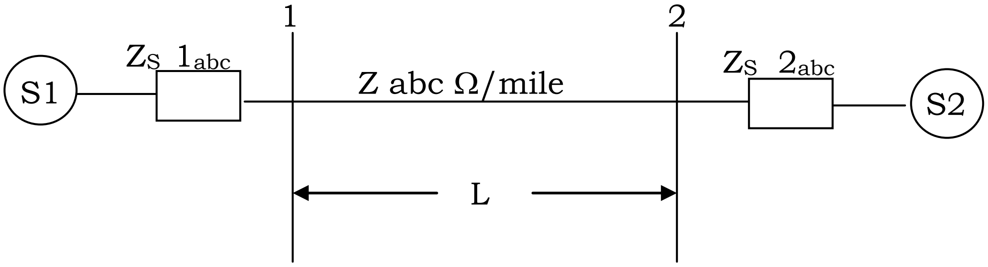

Fig 1: Long transmission line considered for this analysis (long – line = 200 mile = 320 km).

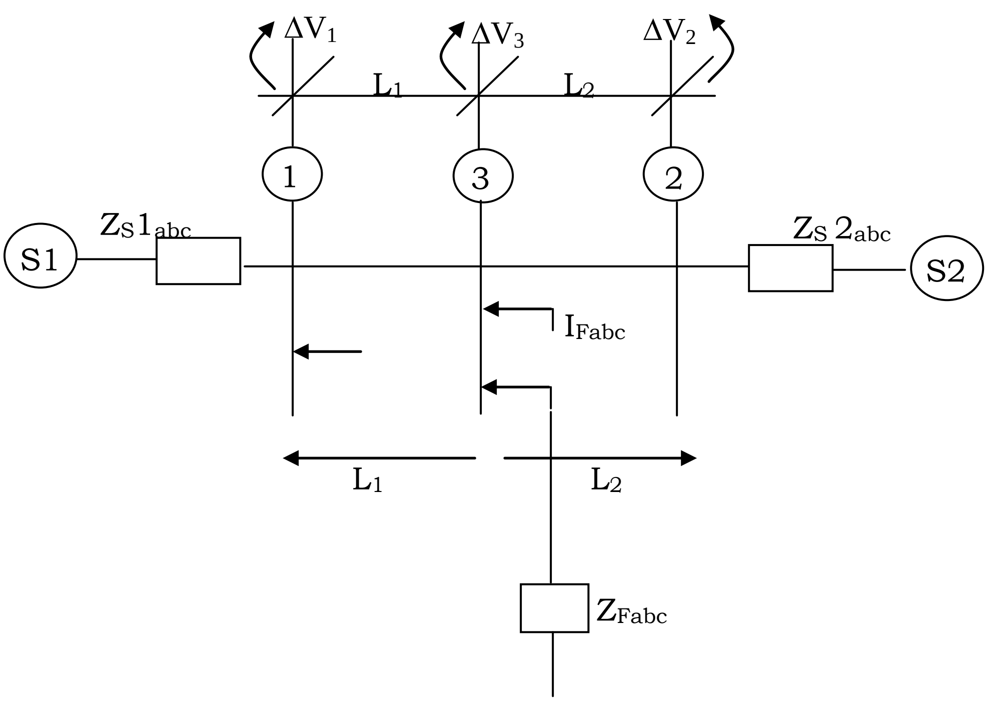

Fig. 2: Transmission line with a fault (bus 3 introduced due to fault initiation).

- Parameter data for the line are:

$R_1 = 0.249168\Omega/\text{mile}$

L_1 = 0.00156277H/mile
C_1 = 19.469E – 9F/mile
R_o = 0.60241Ω/mile
L_o = 0.0048303 H/mile
C_o = 12.06678E – 9F/mile

- The source impedance are as follows:

Sending End:

Zs_1 = 17.177+ j45.5285Ω
Z_{so} = 2.5904 + j14.7328Ω
- Receiving End:
Z_{s1} = 15.31 + j45.9245Ω
Z_{so} = 0.7229 +j25.1288Ω

3. RECOMMENDATIONS

- However, it is requested and recommended that because of fault inevitability and contingency of occurrence of fault introduced into transmission line which in other words could drastically cause a large voltage – drop and could not be tolerated in practice.
- In practice, line are therefore required to incorporate series capacitors to reduce series reactance and the load – current power factor which would increase from 0.9 lag to near unity by the use of shunt capacitors or synchronous compensators at the receiving end.
- The characteristic impedances Z_o is also know as the surge impedance, when a line is terminated in its characteristic impedance, the power delivered is know as the natural load.
- For a loss-free line under natural load conditions the reactive power absorbed by the line is equal to the reactive power generated, this mean that:

$$\frac{V^2}{X_c} = I^2 XL \quad - \quad - \quad (70)$$

And

$$\frac{V}{I} = Z_o = \sqrt{(XL\ XC)} = \sqrt{\frac{L}{C}} \quad - \quad (71)$$

- At this load V and I are in phase all along the line and optimum transmission conditions obtained.
- However in Practice the load impedances are seldom in the order of Z_o. values of Z_o for various line voltages are as follows, values of the corresponding natural loads are shown in breakers: 132KV, 152Ω (50mw); 275KV, 315Ω (240mw); 380KV, 295Ω (490mw).
- The angle of the impedances varies between O and – 15^0. For underground cable Z_o (characteristic impedance = surge impedance or is about one tenth of the overhead line value.
- Parameter of transmission line:

R = Resisters/unit length
L = Inductance/unit length
G = Leakage/unit length
C = Capacitance/unit length
Z = Impedance/unit length
Y = Shunt admittance/unit length
Z = Total series impedance of the line
Y = Total shunt admittance of the line

- Since Z_o is the input impedance of an infinite length of the line, if any line is terminated in Z_o its input impedance is also Z_o.
- The propagation constant (P) represents the changes occurring in the transmitted waves, as its progresses along the line, α measures the attenuation, and β measure angular phase shift. i.e.

$$P = (\alpha + j\beta).$$

- Similarly for a loss free-line, P = jw $\sqrt{(LC)}$ and β = w$\sqrt{(LC)}$ with a velocity of propagation 3 x 10^5km/sec, the wave length of the transmitted voltage and currents at $50^c/_s$ is 6000km.
- Thus lines are much shorter than the wave length of the transmitted energy.

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